Quarkonia Studies in PbPb Collisions by the ATLAS Experiment at LHC

A. Lebedev, *for the ATLAS Collaboration*

Iowa State University, Ames, IA, USA 50011

E-mail: `lebedev@iastate.edu`

Abstract. The measurement of quarkonia production in heavy ion collisions provides a powerful tool for studying the properties of hot and dense matter created in such collisions. We studied the possibility to measure Υ and J/ψ quarkonia families via di-muon decays in heavy ion collisions with the ATLAS experiment at LHC. We present the simulation results for expected reconstruction efficiency, mass resolution, rates, and background estimates for Υ and J/ψ states in PbPb collisions at LHC.

1. Introduction

Observation of J/ψ suppression by NA50 CERN experiment [1, 2], and PHENIX collaboration at RHIC [3] increased interest in the quarkonia studies, although the exact interpretation of both results is still being debated. At LHC, higher collison energy and luminosity will allow us to study, in addition to charmonium, Υ family.

We've studied the possibility to measure Υ and J/ψ quarkonia families via di-muon decays in heavy ion collisions with the ATLAS experiment, by merging single simulated Υ's with flat transverse momentum (p_T) and pseudo-rapidity (η) distributions to central (impact parameter $b = 2fm$) PbPb Hijing events. The full reconstruction chain of the ATLAS analysis package "athena" version 12.0.6 was then run on those merged events. The final histograms were filled with p_T and η weights taken from minimum bias Pythia events.

2. Upsilon Measurement

Υ mass resolution in PbPb events as a function of Υ η and p_T is shown in fig. 1 (left plot). For comparizon, on the same plot, we show mass resolution for single Υ's. As one can see, there is no deterioration of mass resolution in central PbPb events compared to single Υ's. The best mass resolution is achieved in the barrel region ($|\eta| < 1$), and
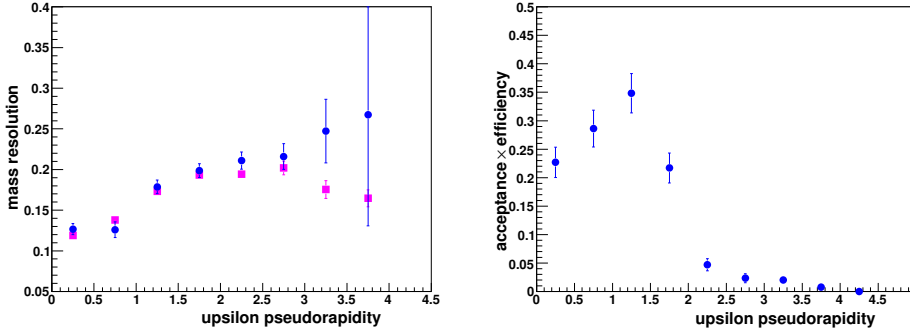
Figure 1. *Left:* Υ mass resolution in central PbPb events as a function of Υ η (blue circles). For comparison, mass resolution for single Υ is shown by magenta squares. *Right:* Υ acceptance times efficiency in central PbPb events as a function of Υ η.

is $\approx 120 MeV$. There is, essentially, no mass resolution dependence on Υ p_T, which can be expected from large Υ mass. Mass resolution can be further improved by restricting η of decay muons and by tightening reconstruction cuts. This, however, results in Υ yield reduction.

To study reconstruction efficiency degradation due to high multiplicity environment, we compared single Υ's merged with central ($b = 2 fm$) PbPb Hijing events. to the same single Υ's merged with minimum bias Pythia events. Single Υ's can not be used for this purpose, since combined muon reconstruction algorithm fails often in single particle events due to uncertainty in the event vertex reconstruction.

Reconstruction efficiency times acceptance ($A\varepsilon$) in central ($b = 2 fm$) PbPb events is shown in figure 1 (right plot). Integrated over p_T and η $A\varepsilon$ for these events is 10.5%±0.1%. For comparizon, integrated over p_T and η $A\varepsilon$ in pp events is 12.3%±0.1%. Thus, efficiency in central PbPb events relative to pp events is ∼ 85%.

Backgrounds and expected yields were estimated using Pythia. In order to make predictions for PbPb collisions, we assumed that both high p_T muons and Υ's scale with the number of binary collisions N_{coll}. Number of binary collisions was taken from Glauber calculation [5]. For minimum bias collisions the predicted $N_{coll} = 400$, for 10% most central collisions perdicted $N_{coll} = 1670$.

Possible sources of background muons include: 1) muons from open charm and beauty decays, and 2) muons from hadron decays, and hadron punch-throughs which can be reconstructed as muons. In order to estimate contributions from the first source, we used Pythia predictions of the decay muon spectra shapes, and cross-sections listed in the CERN Yellow Report [4]. In order to estimate contribution from the second source, we generated single pions and kaons (expected to be the main contributors), run full reconstruction in athena, and made plots of reconstructed muons from these single pion/kaon events. In this way we obtained p_T and η spectra shapes for the background muons coming hadron decays and punch-throughs. Their multiplicities were obtained using cross-sections listed in the Yellow Report. To imitate backckgrounds in
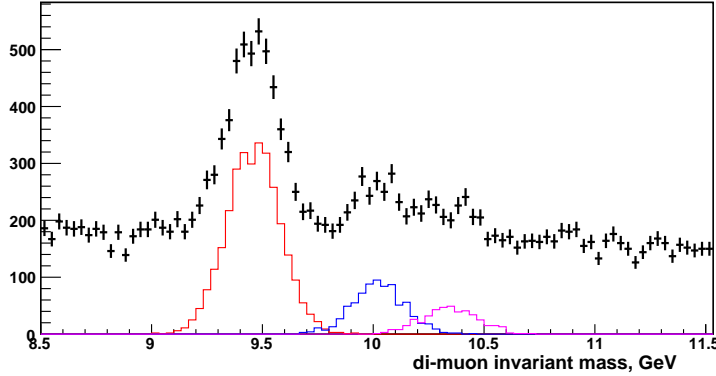
Figure 2. Di-muon invariant mass distribution expected for 24 days of PbPb beamtime, assuming 3kHz collision rate. Acceptance and efficiency corrected. For barrel region only ($|\eta| < 1$).

PbPb collisions, all multiplicities were scaled with number of binary collisions, and then appropriately scaled Υ's were added to the mix. After that, MC simulation was run.

Expected di-muon invariant mass distribution obtained in this Monte-Carlo study is shown in fig. 2. It corresponds to 24 days of PbPb beamtime assuming 3 kHz collisions rate. This plot includes acceptance and efficiency correction, and is for the barrel region only ($|\eta| < 1$). About 15k Υ's are expected to be reconstructed. Υ and Υ' states can be clearly separated. Separation for Υ'' states is less clear, but from physics point of view it is less important since these two states are expected to dissociate at similar temperatures. Signal-to-backgrouns ratio is close to 1.

3. Charmonium measurement

Charmonium measurement will give us additional valuable information about quarkonia suppression. The present charmonium simulation was performed using ATLSIM 7.5.0 package, and GEANT3 (see [6] for more details).

The main problem one faces when measuring J/ψ with the ATLAS detector is the low J/ψ acceptance at low p_T, since muons can be reconstructed only if they have p_T greater than about 2.5GeV. In order to improve J/ψ acceptance we considered two alternative methods of muon reconstruction. The first (standard) method requires a muon to fully traverse the Muon Spectrometer (all 3 muon stations), and only such muon tracks are then associated with the tracks from the Inner Detector. The second method, called "tagging method", requires a muon to pass only through the first muon station. This second method results in worse momentum resolution for muons and more background, but allows the reconstruction of muons with p_T down to $1.5GeV/c$ and increases acceptance for J/ψ several times.

The results of our study of charmonium measurement are shown in fig. 3. This figure shows the p_T distributions of originally generated Υ's, and Υ's reconstructed by different
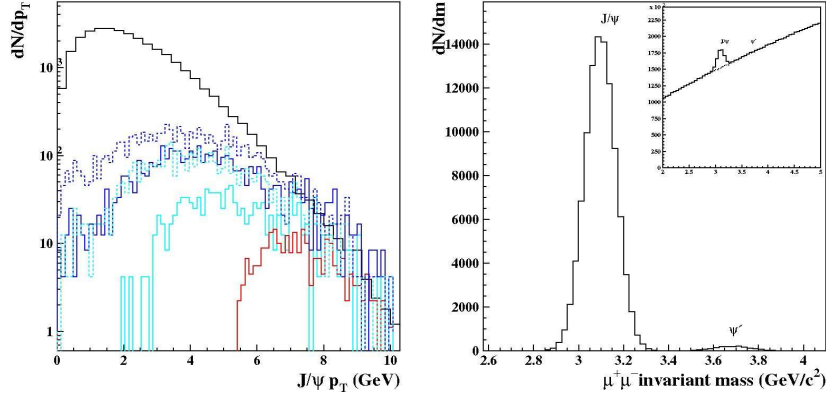
Figure 3. *Left: J/ψ p_T* distribution. Black: original generated distribution; red: full reconstruction (×25); blue: "tagging method" reconstruction. Full lines are for the nominal toroidal field in the Muon Spectrometer, while dashed lines are for half field strength. *Right: J/ψ* mass resolution obtained using "tagging method", and expected di-muon invariant mass distribution for one month of PbPb beamtime (insert).

methods (left side), and expected reconstructed di-muon invariant mass distribution after approximately one month of beamtime (right side). Signal-to-background ratio is expected to be close to 0.2.

4. Conclusions

Υ reconstruction efficiency in heavy ion collisions is not affected by high multiplicity environment, and is the same as that for single Υ's even in most central PbPb events.

Υ mass resolution is good enough to separate Υ and Υ′ states, at least in the barrel region ($|\eta| < 1$). Separation for Υ″ states is less clear, but also possible.

Backgrounds for both charmonium and bottonium measurements are estimated to be at reasonable levels. Signal-to-background ratio for Υ is expected to be close to 1, and for $J/\psi \approx 0.2$. We expect to see Υ and J/ψ peak in one month of beamtime and reconstruct $\approx 15k$ Υ's and $\approx 100k J/\psi$ (using "tagging method").

Reference

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